

## Research Article



# The effect of different confluence confirmation strategies on the obturation of Vertucci type II canal: micro-CT analysis

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### Conflict of Interest

No potential conflict of interest relevant to this article was reported.

### Author Contributions

Conceptualization: Do S, Seo MS; Data curation: Do S; Formal analysis: Do S; Funding acquisition: Seo MS; Investigation: Do S; Methodology: Do S, Seo MS; Project administration: Do S; Resources: Do S; Supervision: Seo MS; Validation: Do S; Visualization: Do S; Writing - original draft: Do S; Writing - review & editing: Seo MS.

## ABSTRACT

**Objectives:** The present study aims to compare the obturation quality of 2 confluence confirmation techniques in artificial maxillary first premolars showing Vertucci type II root canal configuration.

**Materials and Methods:** Thirty artificial maxillary premolars having Vertucci type II root canal configuration were made. They were divided into 3 groups according to the confluence confirmation technique as follows. Gutta-percha indentation (GPI) group (confluence confirmation using a gutta-percha cone and a K file); electronic apex locator (EAL) group (confluence confirmation using K files and EAL); and no confluence detection (NCD) group. In the GPI group and the EAL group, shaping and obturation were performed with the modified working length (WL). In the NCD group, shaping was performed without WL adjustment and obturation was carried out with an adjusted master cone. Micro-computed tomography was used before preparation and after obturation to calculate the percentage of gutta-percha occupied volume (%GPv) and the volume increase in the apical 4 mm. Data were analyzed using 1-way analysis of variance and *post hoc* Tukey's test.


**Results:** Statistically significant difference was not found in terms of the %GPv from the apex to apical 4 mm. However, the NCD group showed a statistically significant volume increase compared with the EAL group ( $p < 0.05$ ).

**Conclusions:** In terms of gutta-percha occupied volume, no significant difference was observed among the 3 groups. Confluence confirmation using an EAL in teeth with Vertucci type II configuration showed less volume increase during canal shaping compared with no confluence confirmation.

**Keywords:** Artificial teeth; Confluence; Micro computed tomography; Obturation

## INTRODUCTION

The objectives of endodontic treatment are to debride and disinfect the root canal space to the greatest possible extent and to obturate the canals as effectively as possible in order to establish or maintain healthy periapical tissues [1]. However, the complex anatomy of root canals often makes it difficult to fulfill the goals of endodontic treatment. The Vertucci type II canal configuration refers to the presence of 2 different root canals that join apically and

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end in a single foramen [2]. In many clinical cases, this configuration is difficult to identify early with traditional intra-oral radiography and is frequently overlooked until the canals are obturated. In such cases, great care must be taken before obturation, since shaping from 2 different directions could create a drop-shaped foramen and parallel walls and lead to stripping of the canal wall or fracture of an endodontic instrument. Therefore, early confirmation of confluence might be important to prevent iatrogenic errors.

Prevalence of Vertucci type II configuration was reported in 41% of the mesial roots of mandibular first molars and in 37.3% of maxillary first premolars [3,4]. The roots presented in the Vertucci type II canal configuration generally contain isthmuses that are located at varying distances from the apical foramen [5]. Several approaches and protocols for cleaning the isthmus areas have been suggested and investigated. However, no protocol or material has been able to make these areas free of hard and/or soft tissue debris and to disinfect them thoroughly [6-8]. The presence of microorganisms in these areas compromises the endodontic treatment outcome, as this is a risk factor for post-treatment apical periodontitis [9]. Therefore, the significance of a 3-dimensional (3D) sealing of the root canal system must be emphasized [10].

There are only a few studies dealing with the obturation of Vertucci type II canal. One recent study compared mineral trioxide aggregate placement technique for orthograde obturation [10]. Since very little research has been done on this topic, a consensus on the ideal technique for obturation of Vertucci type II canal using gutta-percha has yet to be established.

In addition, although a few studies have used human posterior teeth to evaluate the obturation quality in root canals, large variations were observed because of the complex canal anatomy [11-13]. The use of standardized artificial resin teeth can result in more reliable findings when measuring the quality of obturation [14].

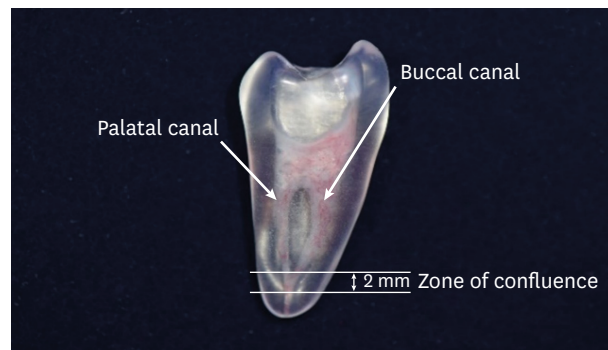
The purpose of the present study was to compare the quality of obturation in the apical third of standardized Vertucci type II artificial premolars with different canal confluence confirmation techniques, using micro-computed tomography (micro-CT). The null hypothesis was that there was no significant difference in the quality of obturation, regardless of the confluence confirmation strategy.

## MATERIALS AND METHODS

### Artificial maxillary first premolars with Vertucci type II configuration

Thirty single-rooted, artificial plastic teeth (DRSK, Hässleholm, Sweden) were used. The outer shape and inner canal space of artificial teeth were customized to reproduce the shape of a common human maxillary first premolar. The customized teeth had open access, a Vertucci type II configuration, a taper of 0.02, and an apical foramen size of #15. The 2 canals merged at 3 mm from the apex. The zone of confluence was set at 2 mm from the apex to 4 mm from the apex (**Figure 1**). In the canal space, there was collagen material simulating pulp tissue. Before the canal preparation, micro-CT images of all the artificial teeth were obtained and homogeneity of the volume was confirmed by preliminary statistical analysis.

The ideal sample size was determined by projecting the power as 0.80 and the effect size as 0.65, with a 2-tailed probability of  $\alpha$  type error of 0.05 [15,16]. The analysis suggested that the



**Figure 1.** Artificial maxillary premolar sample with Vertucci type II canal configuration. Taper of 0.02, apical foramen size of #15, 2 canals merged at 3 mm from the apex. Zone of confluence was from apical 2 mm to apical 4 mm.

sample size for each group should be a minimum of 9. A sample size of 10 for each group was used in the study.

### Preparation of artificial tooth samples

Coronal and middle thirds of the root canals were prepared with #2, #3, and #4 Gates Glidden drills (Dentsply-Maillefer, Ballaigues, Switzerland). A #15 K file (Dentsply Sirona, Ballaigues, Switzerland) was inserted into the canal to determine the working length (WL). The WL was 0.5 mm short of the apical tip point where the file came out and was visible at the apical foramen with the aid of a surgical microscope (Carl Zeiss AG, Munich, Germany) with 8.0 × magnification.

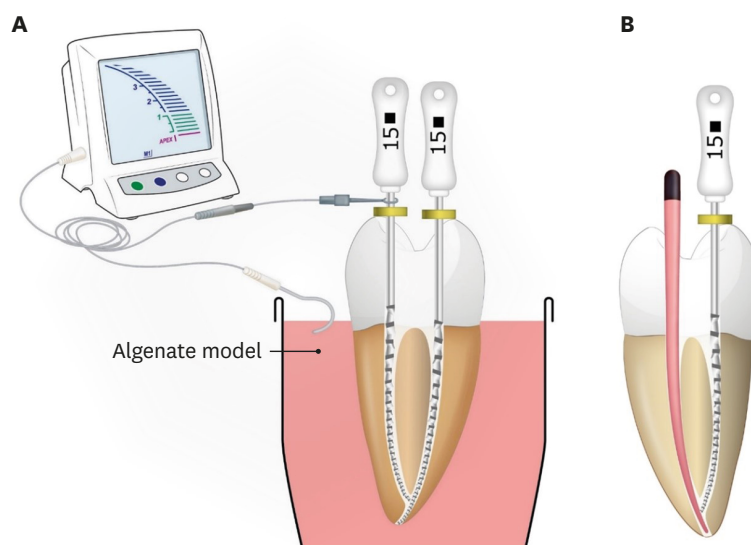
The first canal (palatal canal) was cleaned and shaped using ProTaper Universal (Dentsply-Maillefer) (files S1 and S2), ProTaper NEXT (Dentsply-Maillefer) (files X1, X2, and X3), and Profile (Dentsply-Maillefer) (files #30.06, #35.06, and #40.06), resulting in a master apical file size of #40.06. Endomotor (X-smart, Dentsply-Maillefer) was used for the biomechanical preparation at 300 rpm and 2 Ncm torque. Instruments were removed from the canals and cleaned with gauze after 3 pecking motions. Root canals were irrigated after 3 pecking motions. The specimens were then randomly allocated into 3 groups ( $n = 10$ ).

#### 1. Electronic apex locator (EAL) group ( $n = 10$ )

The artificial teeth were embedded in an alginate model that was developed specifically to test the apex locator (Dentaport ZX, J. Morita Co., Tokyo, Japan) [17]. In the presence of a #15 K file in the first canal (palatal) with the “APEX” sign length of the apex locator, another #15 K file was inserted into the second canal (buccal). The length determined by the “APEX” sign on the apex locator in the second canal, was considered as the modified WL of the second canal. The second canal was shaped to #55.06 size using K3 (Sybron Endo, Orange, CA, USA) rotary file system (**Figure 2A**).

#### 2. Gutta-percha indentation (GPI) group ( $n = 10$ )

A #40.06 size gutta-percha cone (Dentsply-Maillefer) was introduced to the WL in the first canal, and a #15 K-file was inserted in the second canal. The file was removed from the point where resistance was felt. The gutta-percha cone was examined for any grooves, scratches, or fold left by the file, and the modified WL of the second canal was determined. Once the presence of the confluence and its distance from the apical foramen had been confirmed, the cleaning and shaping of the second canal were carried out in the same way as in the EAL group (**Figure 2B**).



**Figure 2.** Schematic drawing of the confluence confirmation strategies. Electronic apex locator (EAL) group: (A) Confirmation of confluence point by using EAL; Gutta-percha indentation (GPI) group: (B) Confirmation of confluence point by using GPI.

### 3. No confluence detection (NCD) group ( $n = 10$ )

The second canal was shaped in the same way as the first canal was shaped. It was shaped with no adjustment of WL and enlarged to a #40.06 file-size. The canals were irrigated between the use of each instrument with 2 mL of freshly prepared 5% sodium hypochlorite (NaOCl), using a syringe and a 27-gauge endodontic needle taken 2 mm short of the WL without engaging the root canal walls. After the preparation, final irrigation was performed with 10 ml of 5% NaOCl using manual dynamic agitation, with master apical sized gutta-percha cone to the WL with gentle push-pull motion; 100 strokes/30 seconds.

## Obturation of the artificial tooth samples

### 1. GPI and EAL group

For the first canal, #40.06 size gutta-percha cone (Dentsply Maillefer) was used. Medium-sized, standardized gutta-percha cones (Dentsply-Maillefer) customized to #55 were used for the second canal. After advancing the master gutta-percha cone for the first canal to WL or within 0.5 mm of WL, the master cone for the second canal was inserted to the modified WL or within 0.5 mm of the modified WL. The master cone for the second canal was trimmed back whenever required to meet this specification. Obturation was completed one canal at a time. Starting with the first canal, gutta-percha was cut 5 mm from the apex using System B (SybronEndo, Orange, CA, USA) at the temperature of 200 °C and packed with Obtura S-Kondenser (Obtura Spartan, Earth City, MO, USA). The second canal was obturated in the same way.

### 2. NCD group

For the first canal, #40.06 size gutta-percha cone (Dentsply-Maillefer) was used. For the second canal, the tip of a medium-sized nonstandardized gutta-percha cone was trimmed back until the 2 cones could be advanced without interruption. Obturation was completed in the same way as that in the GPI and EAL groups.

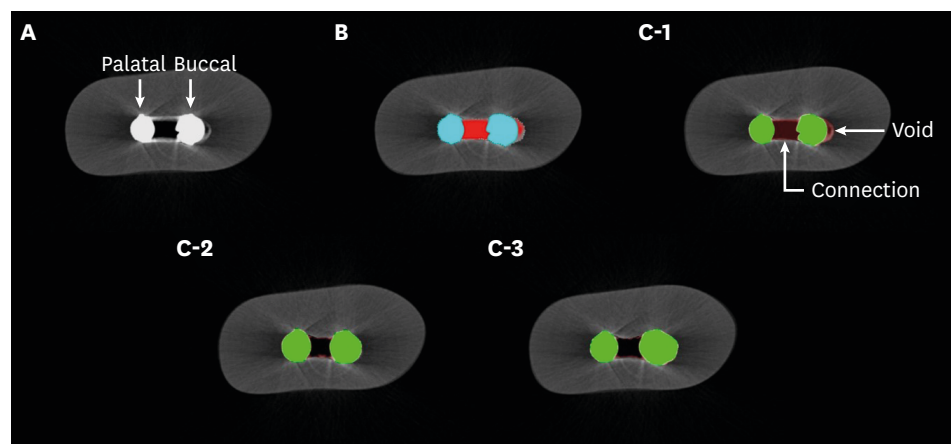
The access cavities were restored with Cavition (GC Dental Industrial Corp., Tokyo, Japan). All the samples were stored in a humidified chamber at 100% relative humidity and at 37 °C

for 7 days, after which they were investigated using micro-CT. For standardization, a single operator performed all the procedures.

### Micro-CT imaging and analysis

A high-resolution micro-CT scanner (SkyScan 1173, Bruker, Billerica, MA, USA) was used to scan the samples. The micro-CT scanner had a pixel size of 13.38  $\mu\text{m}$ , X-ray source voltage of 100 kV, beam current of 100 mA, a 0.5 mm Al/Cu filter, 0.5 step rotation rotated at 360°, integration time of 5 minutes, and 30% beam hardening artifact correction. The obtained images were reconstructed using the NRecon (Bruker microCT, Kontich, Belgium) software and the volume of the filling material and the voids were measured using CTAn (version 1.12.9; SkyScan). The region of interest was the area 0-4 mm from the apex. Three hundred cross-sections were generated for each specimen and the images were saved in the bitmap format. The 3D (volume, increase in volume) and 2D (cross-sectional area) parameters were assessed. Root canal cross-sections (2D) orthogonal to the canal axis on micro-CT were studied in 3 mm from the apex (**Figure 3A**). It was selected as the area most representative of the critical shaping points and the area of confluence.

To calculate the gutta-percha volumes, the original grayscale images were processed using a Gaussian low-pass filter for noise reduction. An automatic segmentation threshold was utilized using CTAn. The binarization process was used in which the range of gray levels was processed to obtain an imposed image (**Figure 3C**). A region of interest was chosen separately for each slice to allow the calculation of gutta-percha volumes (**Figure 3B**). The percentage of the gutta-percha occupied volume (%GPv) was calculated by the formula  $\%GPv = V_M / (V_v + V_M) \times 100$ , where  $V_M$  was the volume of the filling material and  $V_v$  was the volume of the void. Volume increase ( $\Delta\%$ ) was calculated by the formula  $(V_a - V_b / V_b) \times 100$ , where  $V_b$  and  $V_a$  represented the volume assessed before and after preparation, respectively. The percentage of gutta-percha occupied area (%GPa) was calculated by the formula  $\%GPa = A_M / (A_v + A_M) \times 100$ , where  $A_M$  was the area of the filling material and  $A_v$  was the area of the void. An examiner blinded to the preparation protocols performed the analyses.



**Figure 3.** Micro-computed tomography images of the representative specimen (3 mm from apex). (A) Two-dimensional cross sectional virtual slice; (B) Region of interest selection; (C) Representative binarized images to distinguish gutta-percha and voids. The voids, connection, and gutta-percha are marked by an arrow. The image shows cross section of 1) the gutta-percha indentation group, 2) the electronic apex locator group, 3) the no confluence detection group.

**Table 1.** Modified working length (mm) of the second canal of 2 confluence confirmation groups (gutta-percha indentation [GPI] and electronic apex locator [EAL] group)

Group	Sample number (n = 10)										Mean ± SD
	1	2	3	4	5	6	7	8	9	10	
EAL	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5 ± 0.00
GPI	20	19.5	20	20	20	20	20	20	20	19.5	19.9 ± 0.21

SD, standard deviation.

**Table 2.** Means and standard deviations of percentage of gutta-percha occupied area (%GPa), percentage of gutta-percha occupied volume (%GPv), volume increase ([INSERT FIGURE 001]%) from apex to apical 4 mm

Parameters	NCD (n = 10)	EAL (n = 10)	GPI (n = 10)
%GPa	81.38 ± 1.13 <sup>a</sup>	81.93 ± 2.51 <sup>a</sup>	80.31 ± 1.85 <sup>a</sup>
%GPv	90.65 ± 2.25 <sup>a</sup>	88.68 ± 2.48 <sup>a</sup>	90.32 ± 1.21 <sup>a</sup>
Volume increase (Δ%)	69.39 ± 26.37 <sup>a</sup>	38.03 ± 14.31 <sup>b</sup>	58.91 ± 12.99 <sup>a,b</sup>

NCD, no confluence detection; EAL, electronic apex locator; GPI, gutta-percha indentation.

\*Groups identified by the same letter are not significantly different ( $p > 0.05$ ).

### Statistical analysis

The data were statistically analyzed using Kolmogorov-Smirnov test for determination of normal distribution, followed by one-way analysis of variance and *post hoc* Tukey tests to determine if the results were statistically significant ( $p < 0.05$ ). These analyses were performed with the SPSS software (SPSS 12.0 K for Windows, SPSS Inc., Chicago, IL, USA)

## RESULTS

The adjusted WL of the second canal in the EAL group and the GPI group is presented in **Table 1**. The mean %GPa at a cross-sectional area 3 mm from the apex had no statistically significant difference among the groups. The mean %GPv demonstrated no statistically significant difference among the groups (**Table 2**). However, there was a significant difference among the groups in terms of the mean percentage increase in the volume ( $p < 0.05$ ) (**Table 2**). The NCD group showed a higher volume increase when compared with the EAL group ( $p = 0.003$ ). There was no statistically significant difference in volume increase between the NCD group and the GPI group, and between the EAL group and the GPI group.

## DISCUSSION

The majority of the studies evaluating the obturation quality have used teeth with a single canal and few anatomical variations [16,18,19]. The samples of these studies may not reflect the complex root canal anatomy encountered in clinical situations. The artificial teeth used in the present study were customized maxillary first premolars with Vertucci type II canal configuration. In the customizing process, it was supposed that the position of the confluence was a critical factor influencing the outcome of this study. Artificial teeth were designed to have the confluence at 3 mm from the apex. Had it been farther than 5 mm from the apex, it could have been easily filled with backfill. A confluence closer than 1 mm from the apex would have posed a risk of false indicators during confluence confirmation. It is our belief that only one previous study has evaluated the distance between the confluence and the root apex in Vertucci type II configuration. Gambarini *et al.* [3] reported that the average distance between the confluence and the root apex in the mesial root of a mandibular first molar was 2.85 mm. Even the same type of customized artificial teeth may show variations in initial canal shape depending on the sample. We conducted a preliminary micro-CT

examination to ensure that the canal shapes were consistent and that the variations among the samples were negligible.

In the present study, obturation was completed without a root canal sealer. Since it was difficult to standardize the amount of sealer, it could have been an influencing factor in the percentage of gutta-percha volume. Previous studies on this topic did not use a root canal sealer for the same reason [20,21]. Keleş *et al.* [19] have reported that the distribution of sealer within a root canal space is unpredictable, irrespective of the filling method.

In the backfill process of continuous wave compaction techniques, if the tip of the backfilling device does not reach the cut-off point, voids may occur at the transition site [14]. Hence, we cut the gutta-percha off at area 5 mm from the apex using the System B and set the apical 4 mm (0–4 mm from the apex) as the region of interest. Based on pilot studies using several artificial premolar samples, the IAF size of the second canal with the modified WL was set to a size of #40, so we performed the enlargement to a size of #55.06. These were the standardized dimensions considering the shape and taper of the second canal. Keleş *et al.* [19] measured the void distributions in root canal fillings in oval-shaped canals using warm vertical compaction and cold lateral compaction. The %GPv in the apical third was 82.65% and 84.17%, respectively, for these obturation methods. Our results regarding the %GPv in the apical 4 mm area were consistent with these results.

In the present study, no significant difference was found among the 3 groups in terms of the percentage of gutta-percha filled areas according to both 3D and 2D parameters. Therefore, the null hypothesis was accepted. However, in terms of the volume increase, a statistically significant difference was observed. Although a statistically significant difference was found only between the NCD group and the EAL group ( $p = 0.003$ ),  $p$  value between the NCD group and the GPI group was approaching statistical significance ( $p = 0.051$ ). Thus, the groups with the confluence confirmation strategy seemed to show a more conservative root canal shaping compared with the NCD group. It is imperative to prevent procedural errors in clinical situations. Over-preparation of the root canal space may lead to stripping in the danger zone, loss of an apical stop, and/or canal transportation [22-25]. These procedural errors increase the risk of residual infected tissue in the uninstrumented areas of the canal, especially when they occur early in the shaping procedure [26]. It is generally accepted that the strength of an endodontically treated tooth is directly related to the amount of remaining sound tooth structure [27]. Thus, unnecessary removal of healthy dentin can lead to a weakening of the entire root and the confluence confirmation strategies may help to reduce these procedural errors [22,23].

There was a difference in the modified WL of the second canal between the experimental groups. The WL in the EAL group was 0.5 mm (8/10) and 1.0 mm (2/10) longer than in the GPI group. This meant that the confirmed confluence was more apical in EAL group than in the GPI group. In the confluence confirmation procedure for the GPI group, a #40 master cone was inserted in the first canal and a #15 K file was advanced in the second canal to get an indentation on the cone. For the EAL group, a #15 K file was inserted in the first canal and a #15 K file was advanced in the second canal using an EAL. Therefore, the size difference between the cone and the #15 K file in the first canal may explain the difference in the WL in the second canal. In clinical situations, the first canal should be prepared to receive a certain size of gutta-percha for GPI technique, whereas only a glide path establishment is required for the EAL technique. Therefore, WL determination of the second canal using EAL seems to

be the most practical and effective method not only for confirmation of the confluence but also for the effective shaping of the root canal. Further studies are needed to clarify this topic.

## CONCLUSIONS

After the comparison of confluence confirmation techniques using EAL and GPI with no confluence confirmation in the artificial premolars with Vertucci type II configuration, no significant difference was observed among the 3 groups in terms of gutta-percha occupied volume. However, there was a significant difference in terms of volume increase. It suggests that having a confirmation procedure of the confluence using EAL before canal preparation allows more conservative canal shaping than not having a confirmation procedure.

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